The satellite was again observed as a dusky spot on April 23, 1874. The last contact at ingress occurred about $6^h\ 55^m$, the definition being very bad. Six minutes and a half afterwards the satellite was still visible as a very faint luminous spot, but altogether disappeared by $7^h\ 9\frac{1}{2}^m$. At $7^h\ 37^m\ 44^s$, the definition having improved, it became visible as a faint dusky spot, and was soon very conspicuous. It was, however, not near so dark as in April and May 1873. It was seen with difficulty at $9^h\ 29\frac{1}{2}^m$ and became undistinguishable from the disk four minutes afterwards. The last contact at egress occurred about $9^h\ 53\frac{3}{4}^m$.

A transit of this satellite was again observed on July 18, 1874. The last contact at ingress occurred at $5^h\ 25\frac{1}{4}^m$. Occasionally between $5^h\ 56\frac{1}{4}^m$ and $6^h\ 4\frac{1}{2}^m$ I glimpsed a dusky spot near the estimated position of the satellite, but there was no doubt about its visibility at the latter time. The definition was excellent and the satellite soon became conspicuous, although it was projected on one of the faint belts of the planet. It was nearly as dark as the shadows in transit. At $8^h\ 10^m$ it was distinguished with difficulty and was invisible at $8^h\ 18\frac{1}{4}^m$. The bisection at egress took place about $8^h\ 28\frac{3}{4}^m$.

The transit of May 22, 1875, was watched without any trace of the dark phase being seen; indeed, from subsequent observations of transits when the apparent chord of the satellite's path was very short, there appears to be an absence of this phenomenon. This circumstance appears to favour the explanations of Dr. Klein in No. 2014 of the *Astronomische Nachrichten*.

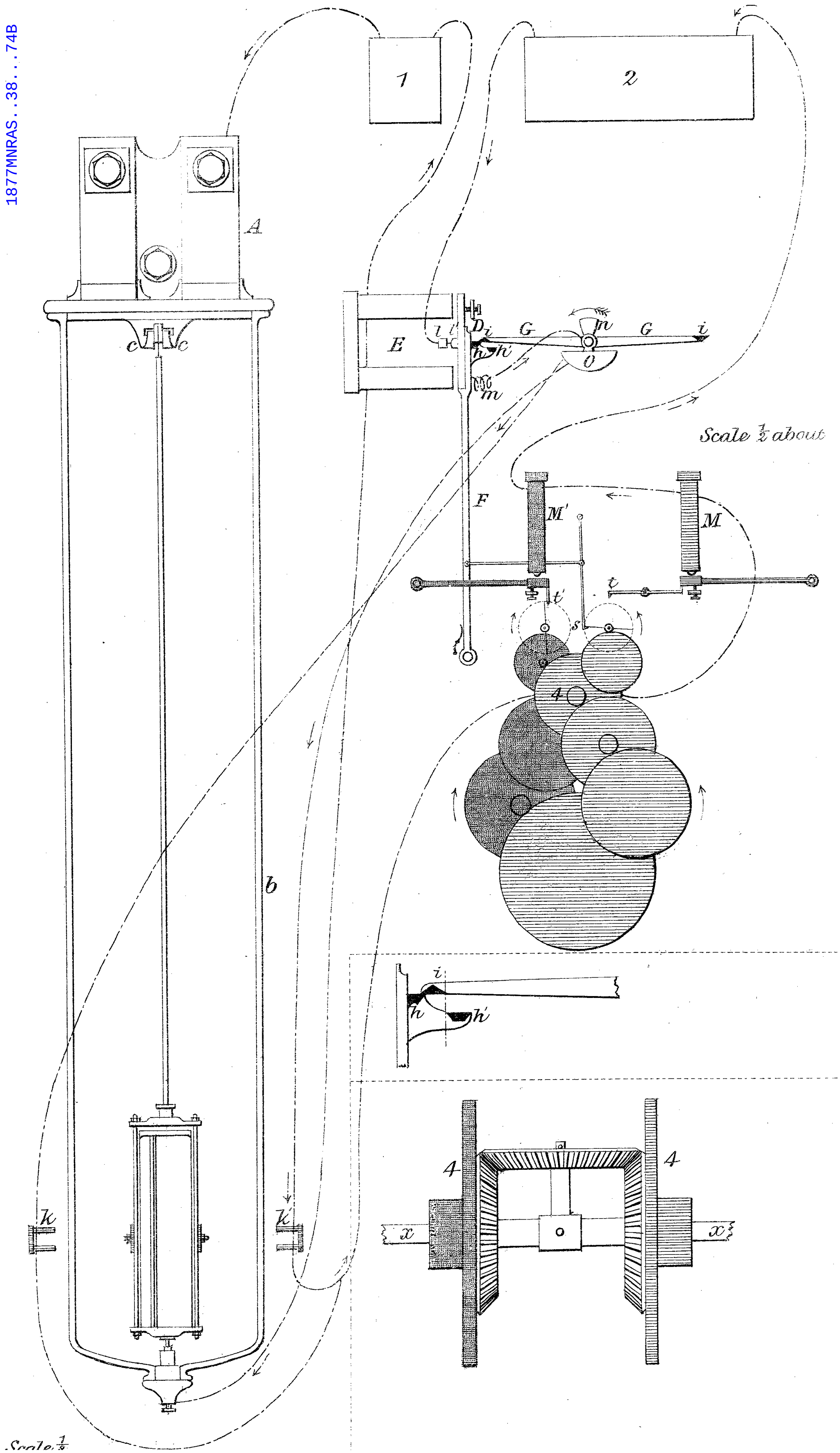
I may mention that the rosy colour of the equatoreal belts of the planet was beautifully seen on May 22, 1875, and May 5, 1877.

Windsor, N.S. Wales,
October 17, 1877.

A New Astronomical Clock.

By C. V. Boys, Esq., Associate of the Royal School of Mines.

In bringing before your notice this new form of Astronomical Clock it will be well first of all to describe the main principles on which it is founded, and then, by describing the details, to show how those principles are carried out. Of course on the pendulum everything depends. The drawing shows a mercury compensation pendulum supported by a spring, but whatever form is thought best might be used. As perfect compensation for atmospheric changes, though now practically almost perfect, can theoretically never be attained, it is an advantage to have the pendulum in a vacuum. This is good for another reason: it requires much less driving power to keep it swinging, and to changes in this power many of the irregularities of clocks are due. Mr. Carrington had a clock in a vacuum which was


1
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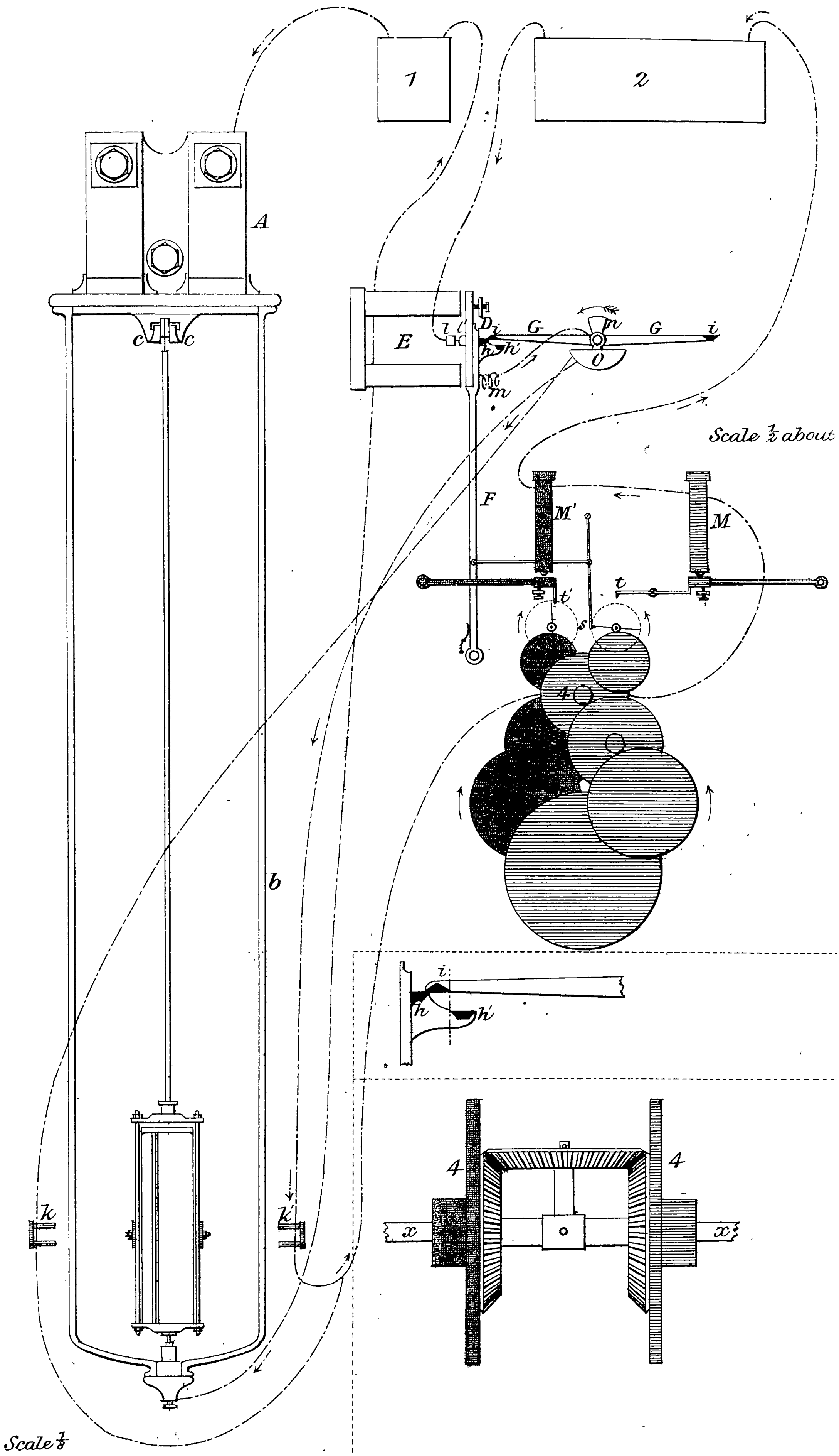
wound up through a stuffing box; but this introduces a new error: the leakage at the stuffing box causes a slow increase of pressure inside the case, and this affects the uncorrected pendulum more than barometric changes in the air do a corrected one. Therefore, if the pendulum is in a vacuum, there must be no moving parts through the vacuum case. The impulse, which must, of course, be invariable, should be given to the pendulum while it is passing the middle of the swing; at all other times, especially at the ends of the oscillations, the pendulum should be absolutely free; also any work done by the pendulum, as unlocking pallets etc., should be at the middle of the swing. The impulse is usually given to the pendulum at a point about a quarter of the way from the top; but this is not the best place. An impulse, even if very powerful, given at the centre of oscillation would tend to turn the pendulum as a whole round its support; but if given anywhere else it would tend to bend the pendulum rod and to strain the supporting spring, and so would not act in the most perfect way. Lastly, a mechanical impulse cannot act so steadily as one due to an attractive force. In all these particulars the clock I am about to describe is as nearly as possible perfect; and, if what I have said is true, it should keep very accurate time.

I now come to the description of the clock itself. A is a powerful bracket secured to the wall; on the lower surface of this a ring is turned, to which the top of the glass case *bb* is secured. This case is afterwards to be exhausted. From the central projecting hooks *cc* hangs the pendulum, carrying at its lower end a small platinum disk, which, at the centre of each oscillation, touches a globule of mercury. 1 is a battery of low power, from which the current proceeds, first, to the supporting bracket, then down the pendulum rod to the mercury globule, round the electro-magnet E, and so back to the battery. Now it is evident that at the centre of each oscillation the electro-magnet E will attract its armature D. D is carried by an arm F, at the top of which is an escapement which the drawing sufficiently explains. The arm GG is driven by clockwork (not shown in the diagram) so that one of the triangular pins i, i' rests on one of the pallets h, h'. From what has been said it will be seen that at every swing of the pendulum the arm G will turn through 180°, that is, will turn 30 times in a minute; thus hands moved by the wheelwork driving the arm may be made to show hours, minutes, and seconds.

The impulse is given to the pendulum from outside the vacuum case in this way:—On each side of the pendulum is fixed a small piece of soft iron by a bolt in a line with the centre of oscillation of the pendulum. Outside the glass case are placed two small electro-magnets k, k'; if these can be alternately made magnetic the pendulum will be kept swinging. 2 is a battery as constant as possible, from which the current passes, first to the platinum block l, then to the platinum hammer l', down the arm F, through the spring m, and on to the axis of the arm G. On this are


1
2
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O
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F
M'
M
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t
s
4
i
h
h'
4
4
x
x
b
k
k
Scale ⅛

fixed two platinum sectors n, n', side by side but in opposite directions. Below there are a pair of mercury troughs o. When the arm G is horizontal one of the platinum sectors is in its trough while the other is out, so, as the arm G turns round, each trough is alternately put in connection with battery 2. Each trough is connected by a wire with one of the electro-magnets k,k'; after passing them the two wires join, pass through the regulating mechanism, and back to the battery. Owing to the platinum pieces l, l' being in contact only when the armature D is attracted, that is, when the pendulum is passing its vertical position, it follows that the pendulum will receive its impulse only at this time; also the impulse will act in a line passing through the centre of oscillation of the pendulum. So far therefore the pendulum is under the conditions stated at first, namely, it swings in a vacuum and so is not affected by atmospheric changes, and it requires a smaller impulse to keep it swinging; there is no moving part through the vacuum case, which can therefore be made perfectly airtight. The impulse is given at the middle of each swing of the pendulum. The impulse is in a line with the centre of oscillation. The pendulum does work, in this case touches the mercury, only in the middle of the swing. The impulse is not given mechanically, but by the uniform action of an electro-magnet. There is one point, however, of the greatest importance not mentioned yet; it is how to keep the impulse, and therefore the current from the battery 2, constant. If at one time the impulse is greater than at another, the pendulum will swing through a larger arc and will therefore go more slowly; but if by any means the impulse can be kept constant, the pendulum will likewise swing through a constant arc. To keep a continuous current constant is an unsolved problem; but the current we have to deal with is intermittent, and though it cannot be kept absolutely constant, yet its practical equivalent can be attained, namely, that the current shall never vary beyond two limits, which limits can be brought as near together as we please. The method of electro-magnet and armature fails to keep a continuous current constant for this reason: the armature, in order to work the regulating machinery, must have a certain amount of play between its stops, and therefore, when at its nearest a decidedly weaker current will be sufficient to keep it attached than would be necessary to attract it when at its greatest distance; therefore fluctuations of a similar amount will take place in the strength of the current. But in an intermittent current the case is quite different: every time the current starts the armature is at the same distance from the electro-magnet, and the same strength of current therefore will be sufficient to attract it every time, but if the current is ever so little weaker the armature will not be attracted. Now, suppose there are two electro-magnets in the same circuit, one of which will for a given strength of current just attract its armature, while the other will just not; then, if the current is of the right strength, one armature only will be attracted, if too weak neither,

if too strong both. These movements of the two armatures may be employed to turn a rheostat, through which the current passes, and so increase or diminish the total resistance according as the current is too strong or too weak. In the drawing, part of the regulating mechanism is coloured blue and part pink* ; the blue part is to regulate the current when too weak, and the pink part when too strong. M, M′ are the two electro-magnets on which the regulating action depends, so arranged that, when the current is right, the blue one only attracts its armature, when too weak neither, when too strong both. The effect of either electro-magnet on its armature depends on the dead weight of the latter, which is invariable, and on the distance, which can be regulated by a screw stop. This is better than using a spring, the strength of which changes with the temperature. This was suggested by my friend Mr. Liveing. Below these electro-magnets are two similar trains of wheels terminating in flies, and as they are to go in opposite directions, the same spring will drive them both.

Wheels 4 of each train run loose on the same axis x, but each carries a bevel wheel gearing with a third, as shown in the lower diagram, so either train is free to run while the other is still, but in so doing it carries the axis x round with half the velocity of its fourth wheel, and in the same direction, according to the formula $e = \frac{n-a}{m-a}$. The axis x turns the rheostat. The parts undescribed will be easily understood from the drawing. Suppose the current of the right strength: then, the moment the pendulum touches the mercury globule, D is attracted and the detent s is drawn back, but at the same time the electro-magnet M attracts its armature and the detent t prevents the blue train from running. The other electro-magnet only attracts its armature when the current is too strong, therefore the detent t' prevents the pink train from running, so both trains of wheels, and therefore the rheostat, keep still. Next suppose the current too weak. As before, the detent t' will be down; but the electro-magnet M, being unable to attract its armature, will leave the blue train free to revolve, so the rheostat will turn a little and diminish the resistance; but if the current is too strong both magnets will attract their armatures, the blue train will be stopped, and the pink one will be free; but it turns in the opposite direction to the blue train, therefore the rheostat will turn a little the other way and increase the resistance. If by any accident m' only were to act, both trains would be set running with an equal velocity in opposite directions and the rheostat would stand still. A single electro-magnet might be used instead of two, arranged to stop the blue train when attracted and the pink one when not attracted. This would keep the strength of the current oscillating on either side of the proper strength. There is no objection to the mercury arrangement $n\,o$, as when the circuit is made and broken the plate is fully

* The blue part is shown by faint shading, the pink part by dark shading.—Ed.

immersed, so there will be no sparks and the resistance will be constant. It is important that the two wires from the mercury troughs *o*, to the electro-magnets *k*, *k′* and on to the junction should have the same resistance, for if not it would be impossible to get a uniform current from the battery 2. Nearly if not quite all the objections to the mercury contact at the lower end of the pendulum are here done away with. The battery 1 may be of very low electro-motive force; the circuit is short, so that there will be hardly any self-induction to produce sparks. The mercury globule being in a vacuum, and if thought well in a hydrogen vacuum, its surface cannot get oxidised. As to the shape of the globule, a circular one, that is, one with a circular horizontal section, would not be good, as, if by chance the pendulum should swing not always in the same plane, but sometimes nearer the front and sometimes nearer the back, the duration of contact would not be uniform, therefore the duration of impulse would vary, which would be fatal. A long globule, then, with parallel sides would be free from this objection.

There is one more point of importance, which is the regulation of the clock. The pendulum would be made as nearly right as possible by the ordinary methods, after which the final regulation could be obtained with the greatest nicety without touching or interfering with the pendulum in any way. As a pendulum swings more slowly in a large arc than in a small, it follows that, by putting the electro-magnets *k*, *k′* nearer to the pendulum, and so increasing their action on it, it would swing through a larger arc and therefore more slowly; and in the same way, by putting them further off, the pendulum would go faster. The two magnets *k*, *k′* would be capable of being moved towards or from the pendulum according as the clock gained or lost. Lastly, the movement of the arm F could be made to send any number of currents every second without in any way interfering with the clock.

Ninth Catalogue of New Double Stars discovered with the 6-inch Refractor. By S. W. Burnham.

The following list comprises the new pairs found with the 6-inch Clark Refractor in the latter part of 1876 and the first part of 1877. During this period most of the time was devoted to the examination of known double stars, and but little attention given to the discovery of new objects. Many of these have been since observed by Baron Dembowski and Professor A. Hall, and their measures are given here.

Since July of the present year this series of double star observations has been continued with the 18·5-inch Clark Refractor of the Dearborn Observatory, and it is hoped that in some respects at least the results obtained have a proportionately increased value.